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Cartridge Loading Random Access Memories

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To establish a frame of reference for evaluating cartridge loaded random access memories (since these promise to assume a prominent position in the computing systems of the immediate and continuing future) and to indicate some methods of comparisions which have been found to be practical and helpful, a simple method of analysis is presented. It will be found to be entirely adequate in most cases and affords a starting point for more exhaustive analyses. The Potter RAM® provides a detailed example.

Two major subdivisions of technology exist in computer random access memory design. Ferrite components and thin films are predominantly used in one class, characterized by very high speed operation. This class has the limitation that extremely large storage capacities are rendered prohibitively expensive by the fact that only a relatively few bit storage locations may be served by common read and write electronics, even when speed is sacrificed in the interests of size and economy.

When large amounts of data are to be stored at low cost the use of a contiguous storage medium is adopted where there are relatively few or only one channel of reading and writing electronics. A very large number of bit locations are served by translating the storage medium past the reading and writing point. In this class of memory magnetic recording is predominant. We are concerned here with a particular aspect of this second category which is variously referred to as file storage, mass storage, bulk storage and so on.

Two major kinds of user situations are encountered where a large amount of data is to be stored and random access is specified. First, all (or most) of the data may be required on line most of the time and second some (or much) of the data can be placed in an off line store much of the time.

This distinction slices random access memory hardware neatly into two classes corresponding to these two different user requirements.

1. Non cartridge loading memories characterized by very large rotating disc stores and large drums.
2. Cartridge loading; employing media such as magnetic cards, small discs, or magnetic tape. We exclude punched cards and magnetic tape on reels from consideration for obvious reasons even though they might be included in a very broad definition of random access memory.

The cartridge loading memories can be further subdivided into two classes according to the type of handler required—relatively expensive or relatively inexpensive—with the dividing line at about $30,000. The more expensive systems find their place, where they may be afforded, for extremely large storage problems where relatively few accesses are made to any given storage location. These systems use magnetic cards or tape strips and are complex and expensive because of the problems associated with the handling of discrete pieces of storage medium at high speed.

In examining the relatively inexpensive cartridge systems which promise to become widespread in use because of the many advantages their combination of characteristics offer, a few basic parameters apply. These are presented in the Table 1 and Fig. 1, which reflect current state-of-the-art.

The geometry of the Potter RAM enables the relatively inexpensive provision of a check-read after write head on each channel giving rise to the distinctive shape of the characteristic curve (shown in Fig. 1). When carrying out the essential process of check reading after writing it is unnecessary to accumulate a further revolution of the recording medium in order to re-access the same record to check read, as is the case wherever the disk approach has been used.

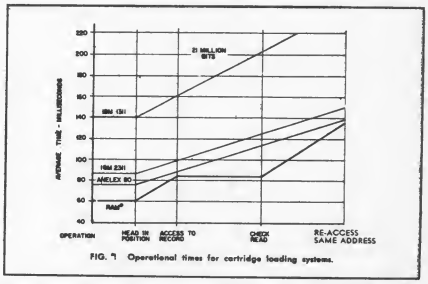

FIG. 1 Operational times for cartridge loading systems.

While Fig. 1 does not of itself afford a comprehensive analysis in a simple diagram, it will be found that this

simple form can be added to by other constructions related to, say, a specified record length, to give an immediate graphical comparison for operations in random mode. For instance, allowance can be made for varying track data densities. However, in the cases studied the differences in basic performance are large enough that these refinements may be safely ignored, with a very few special exceptions.

As an additional aid to effective performance comparisons between the equipments under consideration, it is useful to combine the data tabulated in Table 1, with the rapid performance comparison afforded by Fig. 1. This may be done by computing the effective data rate for several typical record lengths, assuming the average operation times and computing a figure of merit as the ratios of average data rate/price. This now takes into account track information density and the record lengths specified assume roughly equal formatting content.

The various figures of merit may now be rapidly compared by constructing diagrams as shown in Figs. 2, 3, 4, and 5. The diagrams included here were computed using equipment prices only, but if the number of file cartridges were known, this could be taken into account also. A total installation figure of merit comparison would then emerge.

Table 2 gives the basic machine parameters from which the above data may be calculated.

The development of the Potter RAM represents a different approach from that of the other devices listed. Both of the IBM machines and the Anelex machine use metal discs with ferrous oxide-recording surfaces on their faces and are the results of evolutionary development of drums through larger permanent disc memories. Because of the high precision requirements prescribed by high density out-of-contact recording on a non-compliant surface traveling at high speed, the recording elements are expensive and tend to be vulnerable to damage particularly in the inter-changeable-element environment.

The RAM overcomes these difficulties by utilizing a flexible recording medium which is in plentiful supply and inexpensive. Higher performance is readily achieved and simplified machine construction results in lower equipment costs and greater potential reliability. Thus there is a true improvement and not a reduction in cost of storage at the expense of performance with increased complexity and higher equipment cost.

In Figures 2, 3, 4 and 5, the vertical scale is a figure of merit obtained by dividing the effective data rate by the list price of the unit. Points A, B, and C correspond to head positioning, accessing, and check reading, as in Fig. 1

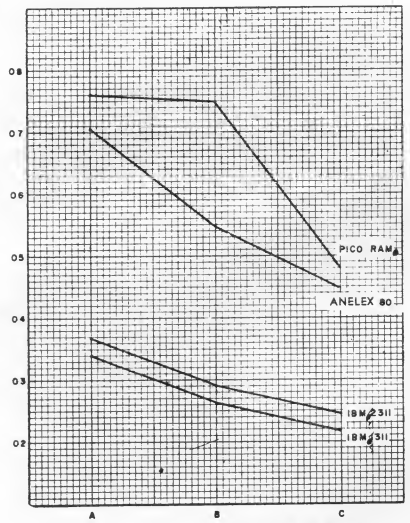

FIG. 2 Characteristics with 100-char record length.

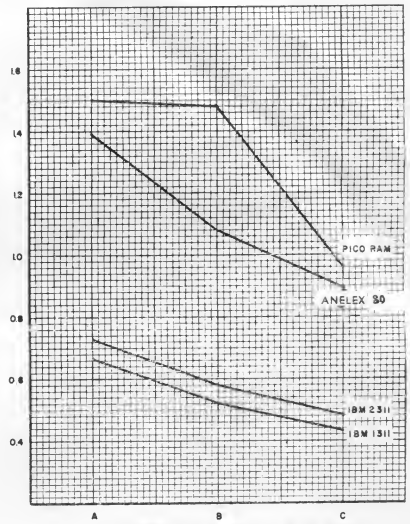

FIG. 3 Characteristics with 200-char record length.

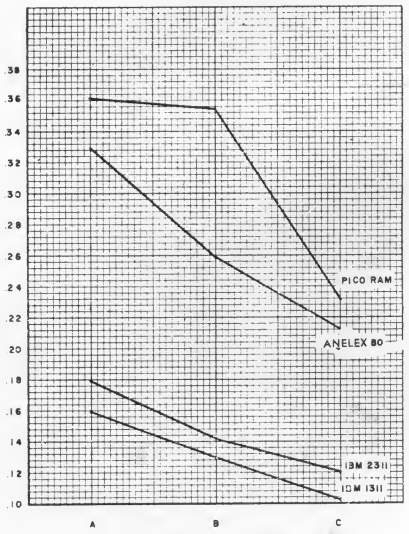

FIG. 4 Characteristics with 500-char record length.

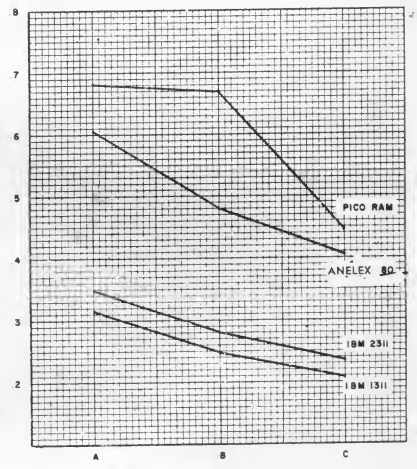

FIG. 5 Characteristics with 1000-char record length.

TABLE 1 Summary Comparison of Cartridge Memories

Mfr. & model	Storage type	On-line capacity (Mbits)	Equip't. cost/bit (¢)	Equip't. cost* ($K)	Cart. cost/bit (¢)	Cart. cost ($)	Avg. access (ms)	Curve (Fig. 1)
IBM 1311	disk	21	0.100	21	0.0024	500	160	A
IBM 2311	disk	56	0.047	26.5	0.00089	500	95	B
Anelex 80	disk	24	0.067	16	0.0014	370	87.5**	C
Potter Ram	tape	50	0.029	14.5	0.0004	200	85	D

* OEM price.
** Since no minimum head shifting time has been published for this machine, it is assumed that this is also the fastest access time where head movement is involved.

TABLE 2 Configuration & Performance Comparison

Mfr. & model	Recording surfaces	Tracks/surface	Track scan (ms)	Avg. Latncy. (ms)	Check-read (ms)	Avg. seek (ms)	Track cap. (Kbits)	Cyl. cap. (Kbits)	Transfer rate (Kc)
IBM 1311	10	100	40	20	40	120	21	210	539
IBM 2311	10	200	25	12.5	25	85	29.2	293	1200
Anelex 80	12	200	25	12.5	25	75	11.2	270	497
Potter Ram	16	112	50	25	0.5	62.5	28	1792	600

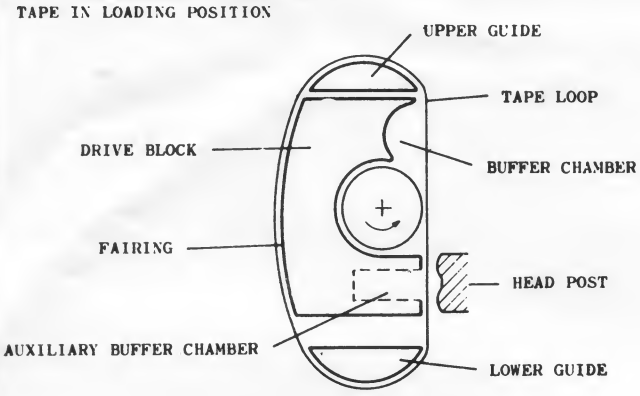

FIG. 7a Tape loop in load condition.

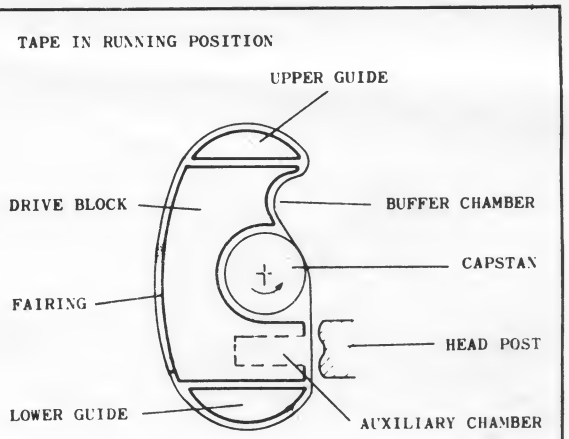

FIG. 7b Tape loop in drive condition.

In selecting a cartridge loading random access memory there is a first and obvious consideration: the device chosen must have the best performance available in relation to its price. Further, the cost of extending total file capacity must be considered. Quite apart from these immediate matters, however, one must also recognize that in this rapidly evolving field it is most desirable to be able to look forward to the possibility of further developments, not only in performance as evidenced by sheer access speed, but also performance in relation to the total system concept, the tasks to be performed and the manner of their performance. These considerations demand a potential flexibility in equipment configuration and functions as well as the promise of continued evolution of the basic technique. Data system designers will be facing demands for specialized combinations of characteristics arising from more sophisticated analyses of the requirements of specific applications.

So far as current practice is concerned, the machine using a flexible magnetic storage medium in loop form offers a highly competitive price performance combination. The loop drive equipment has an attractive robust simplicity which augurs well for reliability of operation and minimal servicing costs. A low cost storage medium is employed in a cartridge which is extremely tolerant in the face of careless handling.

From the point of view of new requirements the RAM approach has much to offer—partly because the drive system is modular and partly because dimensional changes in the storage elements do not have a radical effect upon the drive system. Various combinations of latency time and storage capacity are suggested with the possibility of a single machine able to evince different characteristics at different times as dicated by the job at hand.

The geometry of the machine is suited to adaptation in head arrangements by increasing (or reducing) the number of head pairs or increasing the number of channels acting simultaneously.

SYSTEM DESCRIPTION

Drive System

The loops of high quality digital magnetic recording tape in the cartridge Fig. 6 each have an associated drive unit on the machine. Fig. 7a shows the position of the tape loop which clears the drive assembly and the head as the cartridge is loaded, with the capstan stationary. When the tape loops are aligned vacuum the capstan, deflecting the tape so that its backing surface makes a non-slipping contact with the surface of the capstan, which is now rotating. The tape loop is now in the driving condition as shown in Fig. 7b. Of special importance is the fact that the tape adopts a flying attitude over the surface of the head, maintaining a precise and stable gap between the oxide recording surface and the head profile.

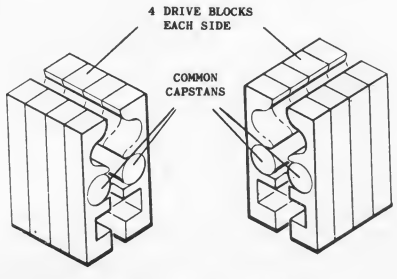

FIG. 8 Drive block for Duplex RAM.

Fig 7 also shows the fixed air bearings which complete the tape path, round the loop, at top and bottom. These fixed elements conduct air under pressure to the bearing surfaces which forms a supporting film preventing contact between the tape and the supports. Thus, the tape loop is entirely supported on an air cushion whilst in motion.

Storage Elements

These comprise loops of high quality digital magnetic recording tape made up from strips 2″ wide which are spliced to form a 30-in. loop. The welding and subsequent treatment of the join are carried out following a specially evolved procedure which produces a loop which may be regarded as continuous in regard to mechanical strength and profile. Data is recorded serially in 112 tracks extending 28″ round the loop at a packing density of 1000 information bits per inch.

Multiple Drive Blocks

The individual drive blocks are arranged in two compact groups on the faceplate of the machine with a common capstan serving each group. Fig. 8 shows the arrangement. A common vacuum supply is connected to all of the buffer chambers so that all loops are engaged in the driving position simultaneously, as part of the automatic load cycle. The twin capstans run in specially designed long life bearings.

Head Post Assembly

All of the record playback heads are mounted in a common head post located between the two groups of loops. See Fig. 10. The position of the head post can be seen Fig. 8. The profile of the head post is contoured with a smooth finish, to define the desired stable flying attitude for the tape. The head post forms a rigid beam structure and has a cantilevered support track which permits the heads to be traversed over the recording surfaces under the control of a head post positioning mechanism.

Head Positioning Mechanism

Because the head positioning system demands only simple linear movement of a single assembly over a very short distance a singularly robust and uncomplicated control mechanism is possible. This takes the form of a binary input positioning linkage sometimes referred to as a "whiffle-tree," Fig. 12. Five equal amplitude input deflections acquire binary weightings from the linkage relationships, providing 28 precisely repeatable postions of the head post with very fast head shifting.

Machine Console

Fig. 13 shows the complete machine with the tape pack cartridge in position prior to loading and in outline, the cartridge in the loaded position.

Twin Cartridge Machine

In addition to the RAM described above, an alternative version has been developed. Fig 14 shows the layout of this version compared with the layout of the single cartridge machine. The twin cartridge machine has the same on line capacity and performance as the single cartridge machine; indeed, the machine description given above is directly applicable other than in the case of simple changes implied by the new layout which drives the 16 loops in two physically separate groups of 8 but still retains twin common capstan drives and a single head shifting mechanism etc. As evidence of the inherent flexibility of the machine concept, the alternative version is offered at the same price and specifications as the single cartridge machine.

The important operational advantage of the Duplex Ram lies in its application in single cartridge applications. The ability to copy either the partial or entire data content from one cartridge to another avoids the necessity for two machines in many cases where the on line capaicty of one machine is adequate. Furthermore, the ability to load certain basic data on one cartridge in association with many different file cartridges provides an operational flexibility which is invaluable in many applications. ■ ■

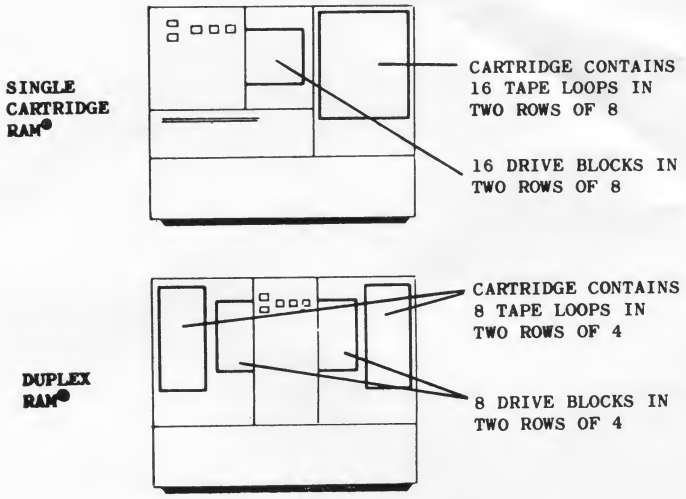

FIG. 14 Comparison of single cartidge and duplex machines.

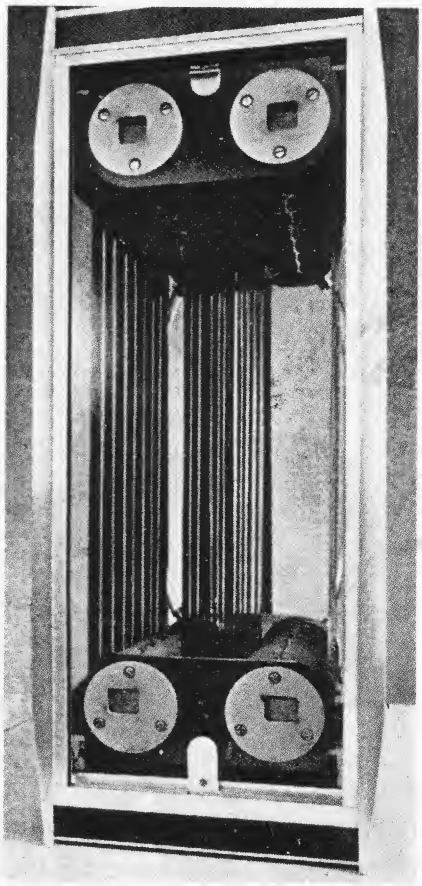

FIG. 6 System uses loops of magnetic tape as storage medium. This cartridge contains 16 loops of 2-in. wide tape.

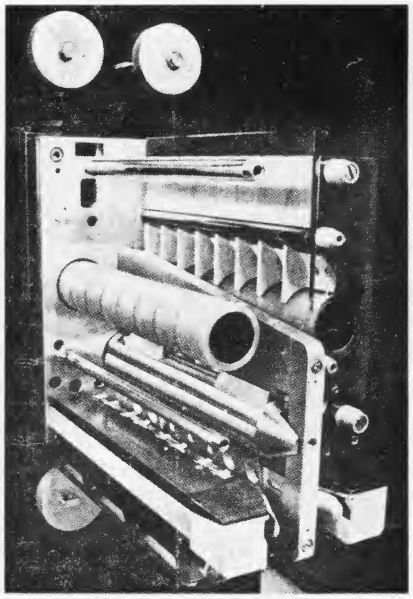

FIG. 10 Drive block with section removed to show head post.

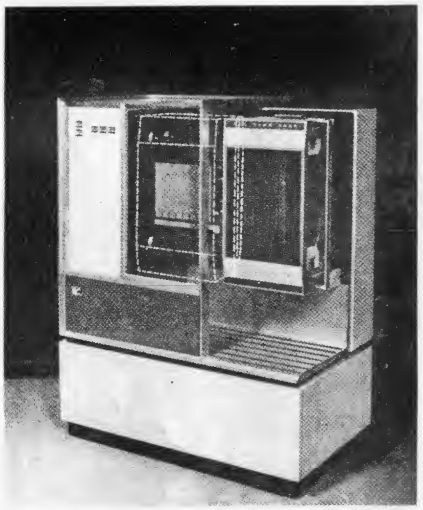

FIG. 13 Complete machine, with cartridge ready to load. Dashed line shows loaded position.

The author wishes to acknowledge the help received from many interesting discussions of the RAM concept both with friends in the EDP Industry and colleagues at Potter Instrument Company, in particular Andrew Gabor and Eleuthere Poumakis.